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Sugiura et al.

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(54) **INDUCTIVE COUPLING**

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E21B 47/12 (2012.01)
H02J 50/12 (2016.01)
H02J 50/40 (2016.01)
E21B 17/042 (2006.01)
E21B 17/10 (2006.01)
E21B 47/00 (2012.01)

(52) **U.S. Cl.**

CPC **E21B 17/028** (2013.01); **E21B 17/042** (2013.01); **E21B 17/1078** (2013.01); **E21B 47/00** (2013.01); **E21B 47/12** (2013.01); **H02J 50/12** (2016.02); **H02J 50/40** (2016.02)

(58) **Field of Classification Search**

CPC E21B 17/003; E21B 47/01; E21B 17/028; H02J 50/12; H02J 50/40
See application file for complete search history.

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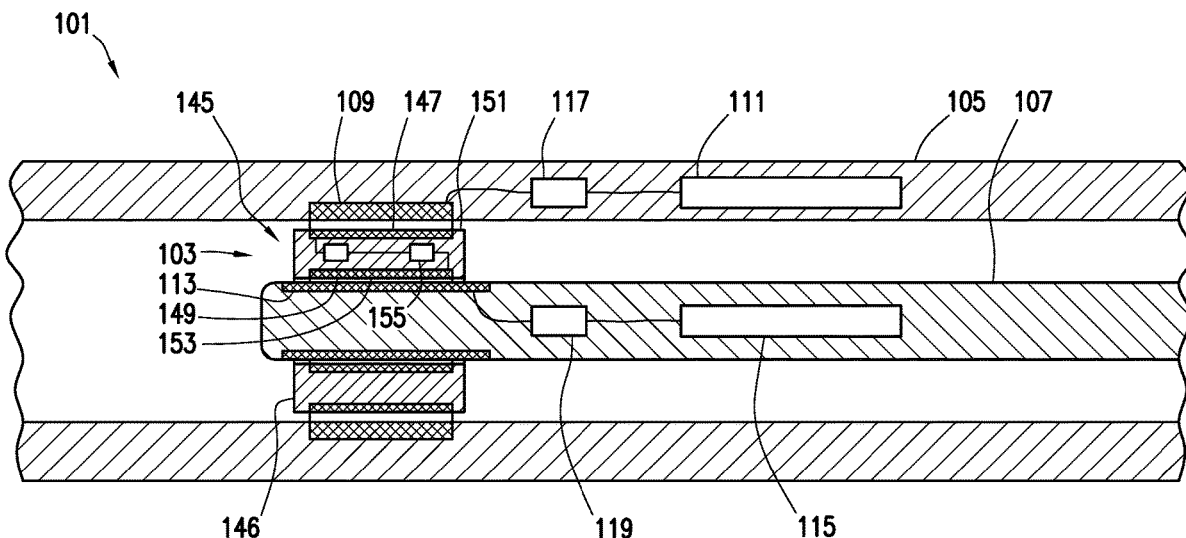
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(57)

ABSTRACT

An inductive coupler includes a first transceiver electrically coupled to a first coil through a first tuning circuit. The inductive coupler may also include a second transceiver electrically coupled to a second coil through a second tuning circuit, where the second coil is positioned substantially concentric with the first coil.

15 Claims, 9 Drawing Sheets



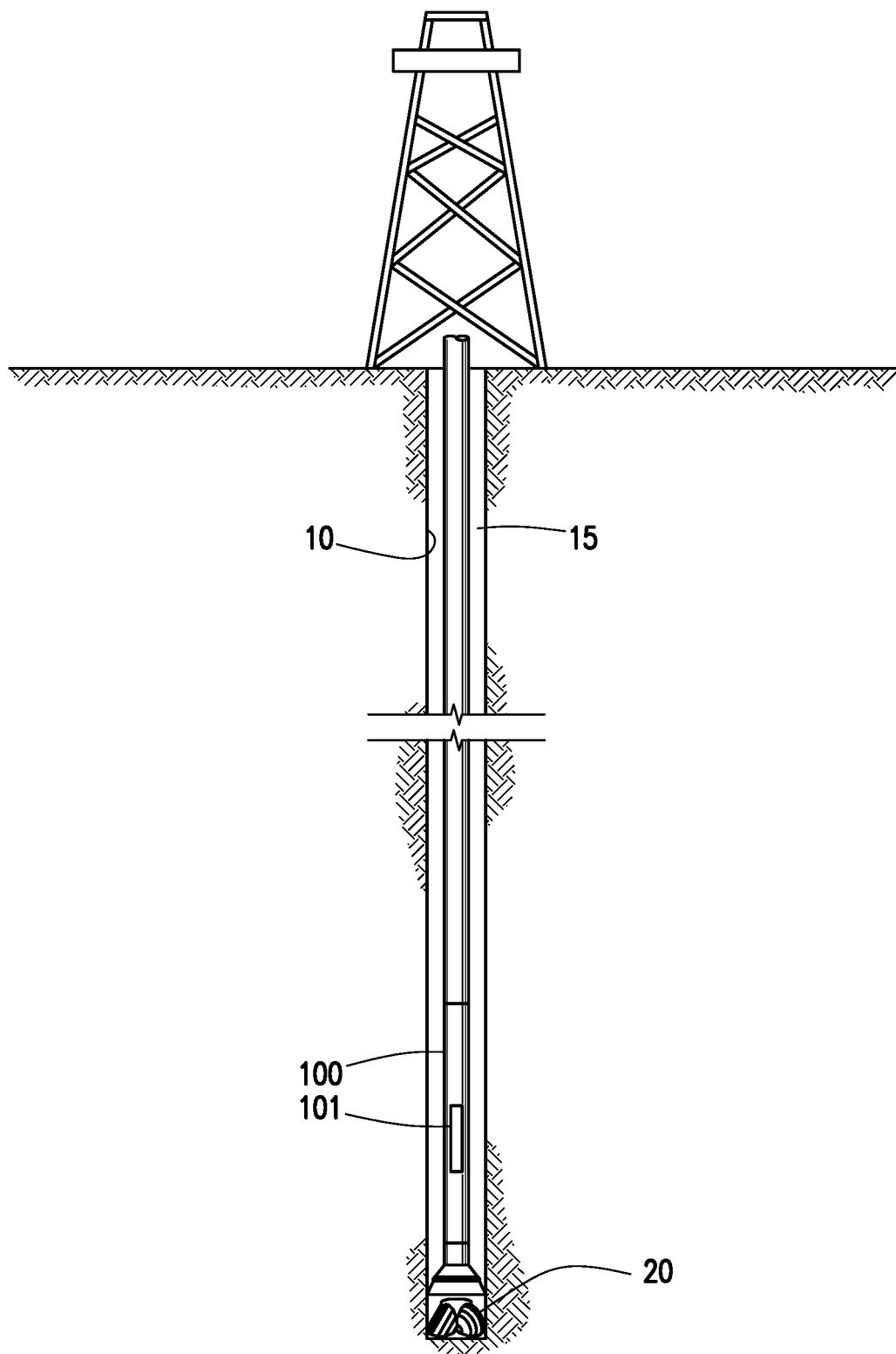


FIG. 1

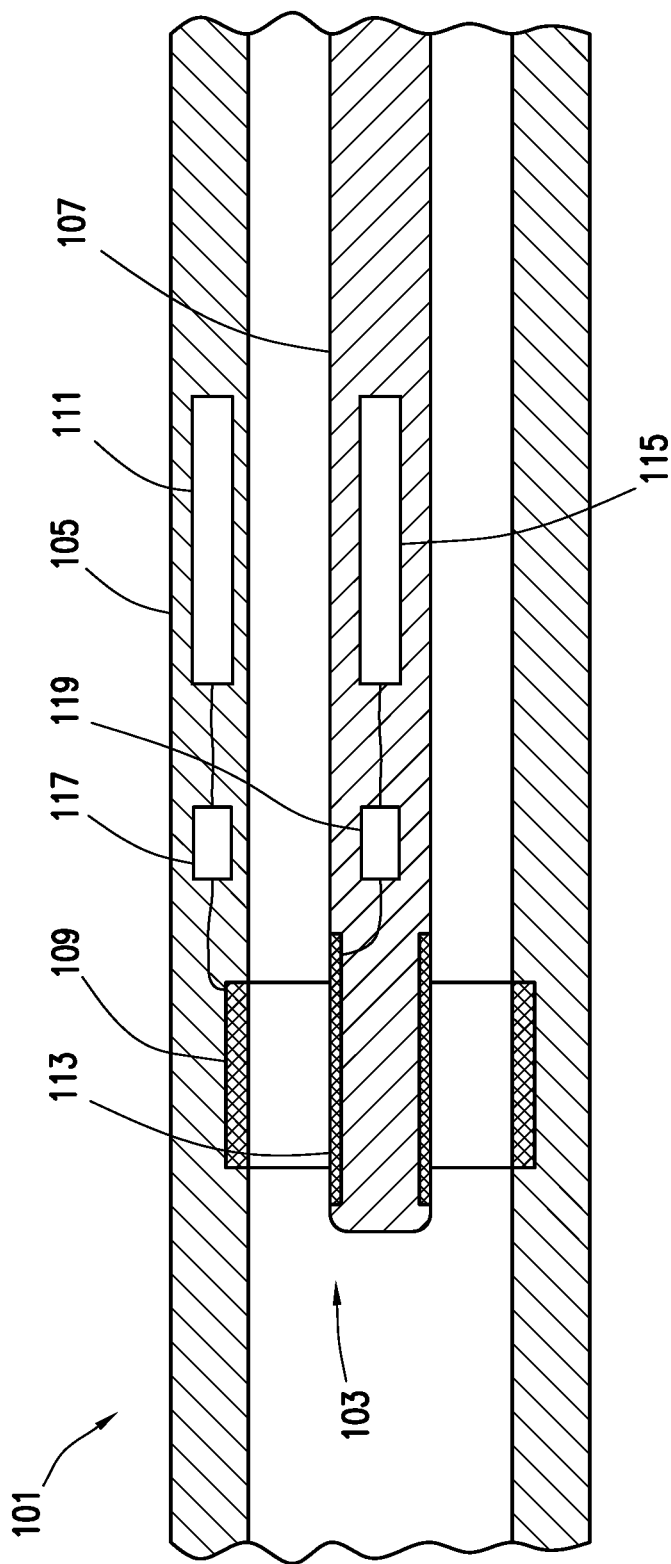


FIG. 2

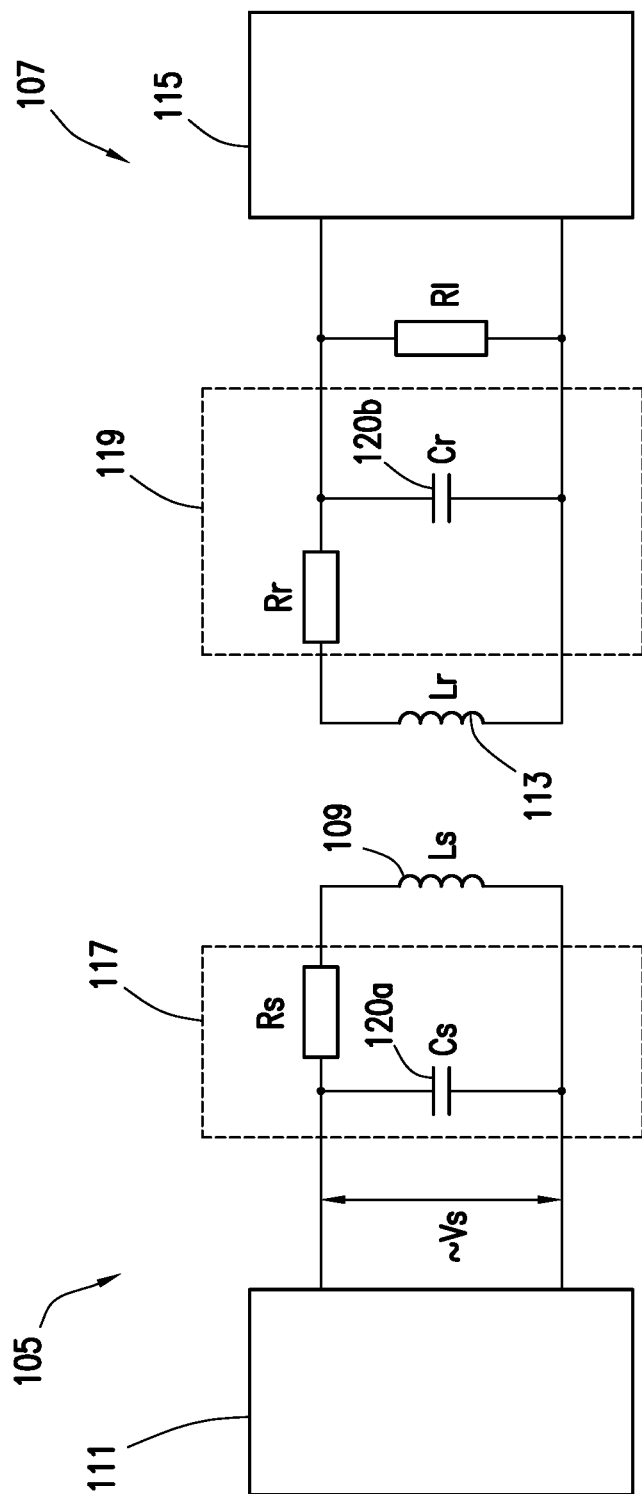


FIG. 3

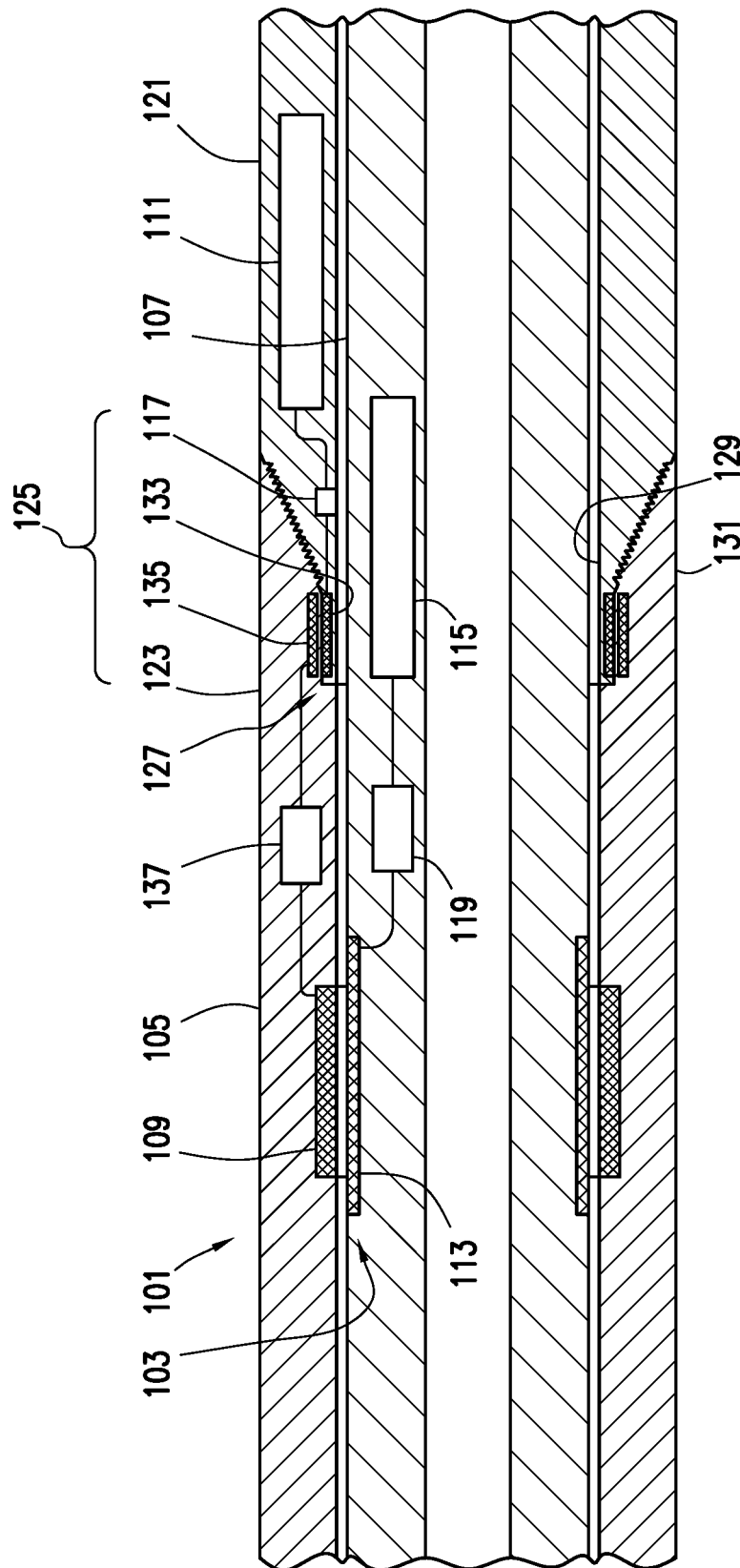


FIG. 4

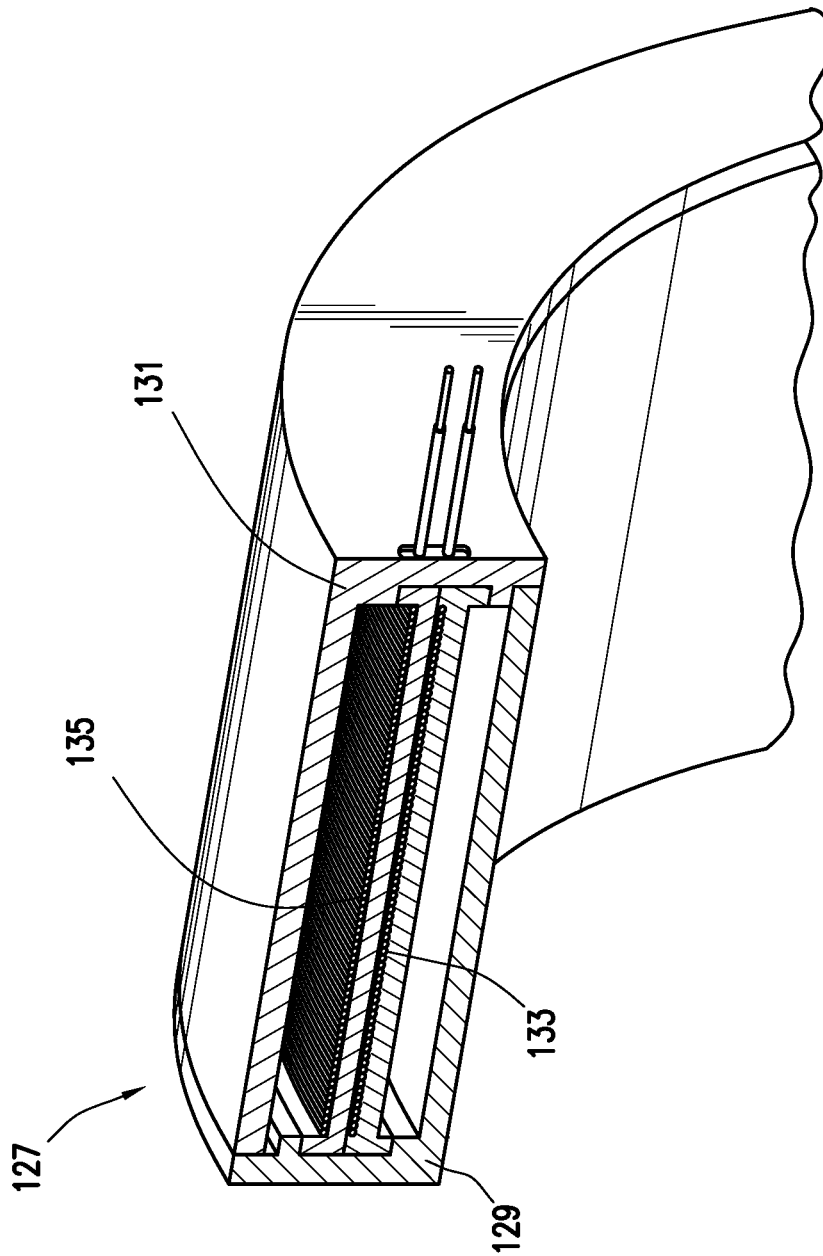


FIG. 4A

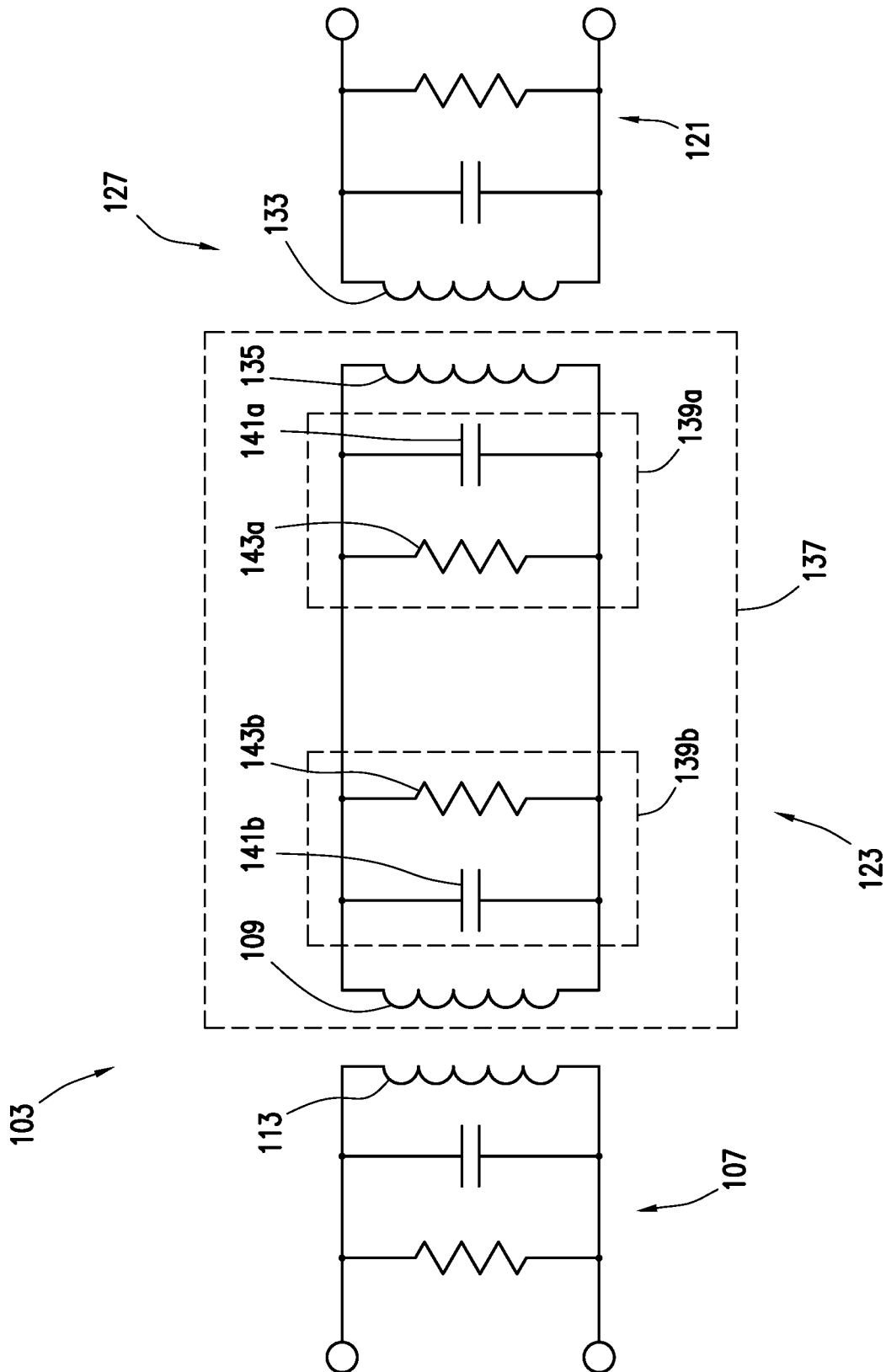


FIG. 5

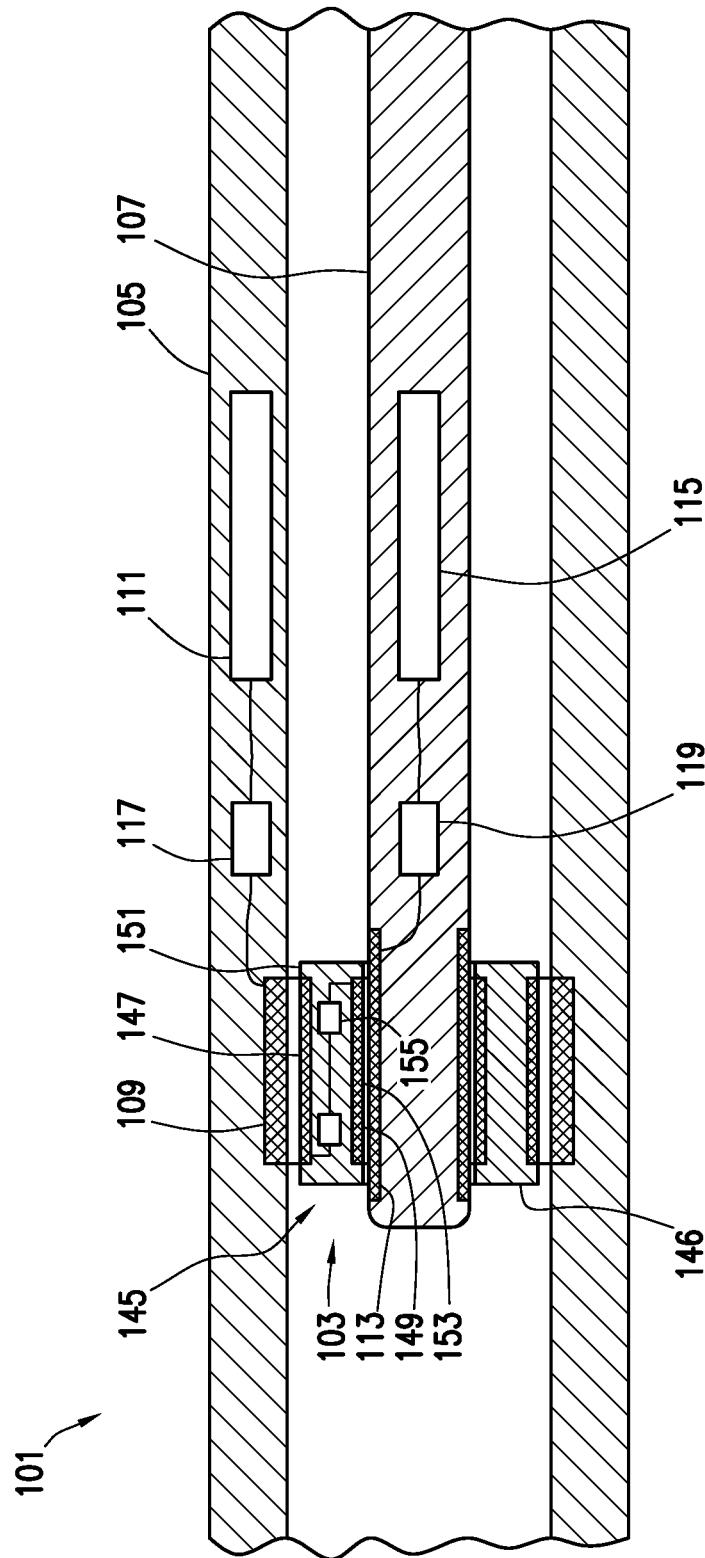


FIG. 6

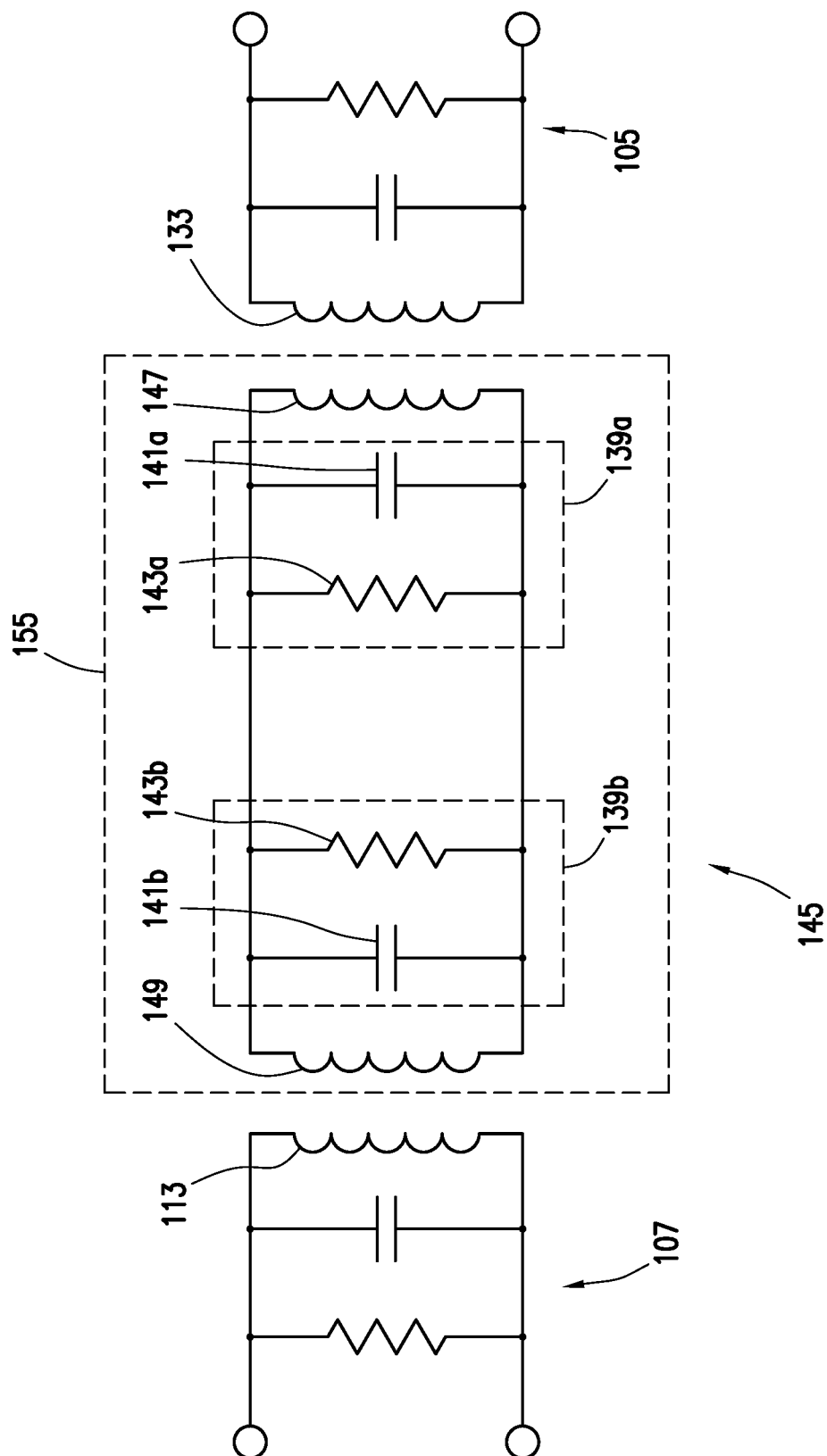


FIG. 7

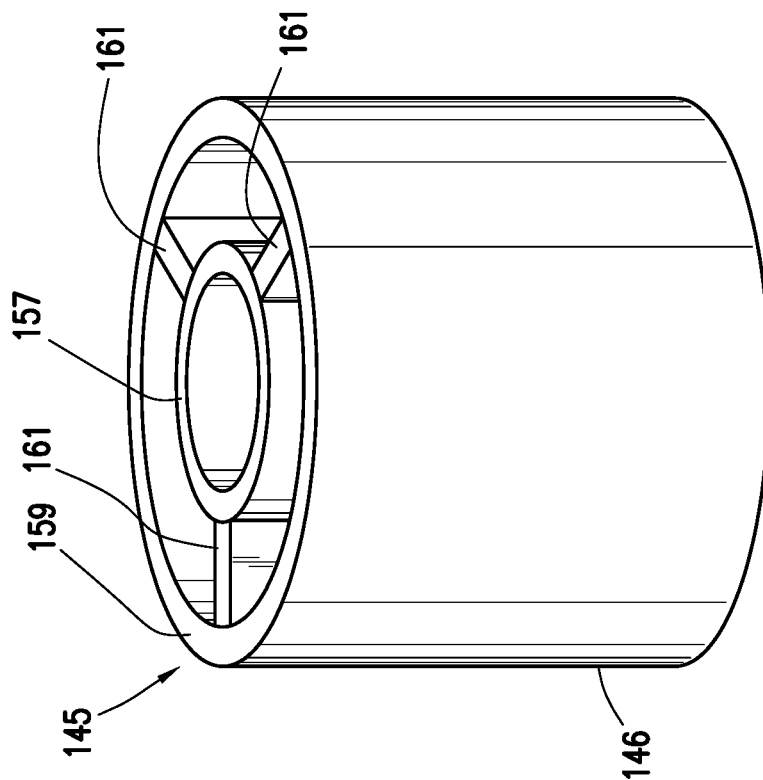


FIG. 9

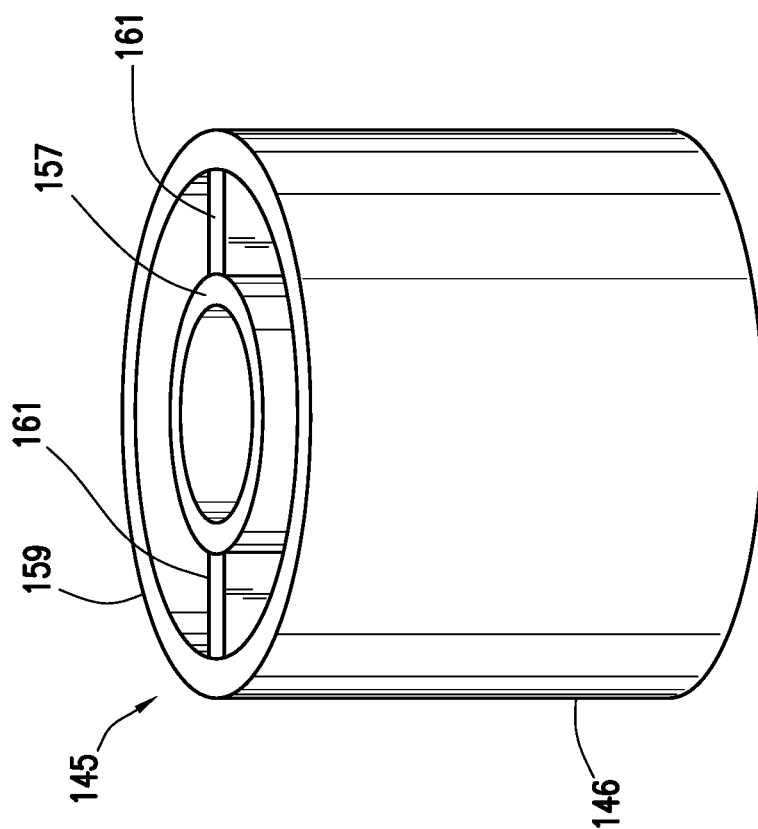


FIG. 8

INDUCTIVE COUPLING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application which claims priority from U.S. utility application Ser. No. 15/174,813, filed Jun. 6, 2016, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD/FIELD OF THE DISCLOSURE

The present disclosure relates to data and/or electrical power transmission in a downhole tool.

BACKGROUND OF THE DISCLOSURE

When drilling a wellbore, data may be communicated between subcomponents of a downhole tool. Because subcomponents may be located in different structures of the downhole tool, direct data connections may be difficult to configure. Additionally, the downhole environment may cause wear or damage to mechanical electrical connections. Mechanical connections such as rotary connectors may be expensive and may fail in the downhole environment. Mechanical connections may also wear over time, requiring maintenance operations to be performed. Mechanical connections may also be susceptible to fluid contamination.

For example, in a rotary steerable system (RSS), data may be communicated between subcomponents of the RSS located in rotating components of the bottomhole assembly and subcomponents of the RSS located in nonrotating components of the bottomhole assembly.

SUMMARY

The disclosure provides for an inductive coupler. The inductive coupler includes a first transceiver electrically coupled to a first coil through a first tuning circuit. The inductive coupler also includes a second transceiver electrically coupled to a second coil through a second tuning circuit, where the second coil is positioned substantially concentric with the first coil.

The disclosure also provides for a downhole tool. The downhole tool includes a collar with a primary collar and an intermediate collar and a probe positioned within the collar. The downhole tool also includes a collar transceiver positioned within the primary collar, the collar transceiver electrically coupled to a male coil through a collar tuning circuit. In addition, the downhole tool includes a probe transceiver positioned within the probe, the probe transceiver electrically coupled to a probe coil through a probe tuning circuit. The downhole tool includes a female coil positioned within the intermediate collar and a collar coil positioned within the intermediate collar. The collar coil is electrically coupled to the female coil through an intermediate tuning circuit.

The disclosure provides for a centralizer for supporting a probe within a collar of a downhole tool. The centralizer includes a centralizer body and an outer coil, the outer coil positioned at an outer surface of the centralizer body. The centralizer also includes an inner coil, the inner coil positioned at an inner surface of the centralizer body, and the inner coil electrically coupled to the outer coil through a centralizer tuning circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

The present disclosure is best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. 1 depicts an overview of a downhole tool in a wellbore.

FIG. 2 depicts a cross section view of an inductive coupler consistent with at least one embodiment of the present disclosure.

FIG. 3 depicts a schematic view of the inductive coupler of FIG. 2.

FIG. 4 depicts a cross section view of an inductive coupler consistent with at least one embodiment of the present disclosure.

FIG. 4A depicts a partial cross section perspective view of the inductive coupler of FIG. 4.

FIG. 5 depicts a schematic of a circuit including a tuning circuit of an inductive coupler consistent with at least one embodiment of the present disclosure.

FIG. 6 depicts a schematic view of a coil centralizer consistent with at least one embodiment of the present disclosure.

FIGS. 7, 8, 9 depict perspective views of coil centralizers consistent with at least one embodiment of the present disclosure.

DETAILED DESCRIPTION

It is to be understood that the following disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

FIG. 1 depicts an overview of a wellbore consistent with at least one embodiment of the present disclosure. Wellbore 10 may be formed by drill string 15. Drill string 15 may include drill bit 20 for forming wellbore 10. In some embodiments, bottomhole assembly 100 may be positioned at the end of drill string 15 within wellbore 10. In some embodiments, bottomhole assembly 100 may include one or more downhole tools 101. Although discussed with respect to drill string 15, one having ordinary skill in the art with the benefit of this disclosure will understand that the present disclosure may be utilized with any downhole tool 101 without deviating from the scope of this disclosure and need not be coupled to a drill string. For example and without limitation, in some embodiments, downhole tool 101 may be positioned within wellbore 10 by a drill string, casing string, wireline, coiled tubing, or any other suitable delivery mechanism.

In some embodiments, as depicted in FIG. 2, inductive coupler 103 may be utilized to transmit data between different subcomponents of downhole tool 101 or between different downhole tools 101. Subcomponent, as used herein, means any portion or subdivision of a tool. For example and without limitation, in some embodiments,

inductive coupler 103 may be used to transmit information from collar 105 to probe 107. In some embodiments, collar 105 and probe 107 may be mechanically coupled such that they are rotatable relative to each other. In some embodiments, collar 105 and probe 107 may be mechanically coupled such that they are not rotatable relative to each other. Although described as transmitting between collar 105 and probe 107, one having ordinary skill in the art with the benefit of this disclosure will understand that inductive coupler 103 may be used to transmit data between any two subcomponents of downhole tool 101 or between different downhole tools 101.

With further attention to FIG. 2, in some embodiments, collar 105 may include collar coil 109. Collar coil 109 may be electrically coupled to collar transceiver 111 located in collar 105. In some embodiments, probe 107 may include probe coil 113. Probe coil 113 may be coupled to probe transceiver 115. Transceivers 111 and 115 may be utilized to transmit and receive data transmitted inductively between collar coil 109 and probe coil 113. In some embodiments, collar coil 109 and probe coil 113 may be used for bilateral communication between collar 105 and probe 107. In some embodiments, although described as transceivers 111 and 115, one having ordinary skill in the art with the benefit of this disclosure will understand that one or both of transceivers 111 and 115 may instead be solely a transmitter or receiver which utilizes collar coil 109 and probe coil 113 for unilateral communication between collar 105 and probe 107. In some embodiments, transceivers 111 and 115 may have separate transmitters or receivers.

In some embodiments, collar coil 109 and probe coil 113 may be aligned longitudinally along downhole tool 101. In some embodiments, probe coil 113 may be positioned at least partially radially within collar coil 109. In some embodiments, collar coil 109 and probe coil 113 may be generally coaxial. In some embodiments, collar coil 109 and probe coil 113 may be formed from windings of wire such that when electric current is passed therethrough, a magnetic or electromagnetic field is induced. Likewise, when a magnetic or electromagnetic field is passed through collar coil 109 and probe coil 113, an electric current is generated in the coil. In some embodiments, transceivers 111 and 115 may be electrically coupled to coils 109 and 113 respectively to generate electric current in or receive electric current from coils 109 and 113 to transmit data between collar 105 and probe 107.

In some embodiments, collar coil 109 and probe coil 113 may be positioned away from magnetic or conductive materials. In some embodiments, without being bound to theory, eddy currents induced within magnetic materials may, for example and without limitation, reduce loss in the transmitted electric current. In some embodiments, void spaces between collar coil 109 and components of collar 105 and between probe coil 113 and components of probe 107 may be filled with a material having high magnetic permeability and low electrical conductivity. For example and without limitation, in some embodiments, ferrites may be utilized. Ferrites, as understood in the art, may be ceramic compounds of transition metals with oxygen, which are ferromagnetic but nonconductive. In some embodiments, high-magnetic permeability, low conductivity steel may be used in the void spaces.

In some embodiments, collar transceiver 111 may be electrically coupled to collar coil 109 through collar tuning circuit 117. In some embodiments, probe transceiver 115 may be electrically coupled to probe coil 113 through probe tuning circuit 119. In some embodiments, by including

tuning circuits 117 and 119 on both collar 105 and probe 107, inductive coupler 103 may be referred to as “double tuned”. In some embodiments, one or more tank circuits or resonant tank circuits may be utilized as tuning circuits 117 and 119. For example, one or more of parallel tank circuits and series tank circuits may be utilized. In certain embodiments, at least one parallel tank circuit and at least one series tank circuit may be used. As depicted in FIG. 3, in some embodiments, tuning circuits 117 and 119 may include one or more components such as capacitors 120a and 120b. In some embodiments, capacitor 120a and collar coil 109 may form a parallel resonant tank circuit. In some embodiments, capacitor 120b and probe coil 113 may form a parallel resonant tank circuit. As depicted in FIG. 3, Rs and Rr represent the resistance of capacitors 120a and 120b and collar coil 109 and probe coil 113 respectively. The resonant frequency of each tuning circuit 117 and 119 may be given by:

$$\omega = \frac{1}{\sqrt{L_1 C_1}} = \frac{1}{\sqrt{L_2 C_2}}$$

where L1 is the inductance of collar coil 109, L2 is the inductance of probe coil 113, C1 is the capacitance of capacitor 120a of collar tuning circuit 117 and C2 is the capacitance of capacitor 120b of probe tuning circuit 119. By selecting capacitors 120a and 120b having capacitance based on the inductance values L1 and L2 of coils 109 and 113 respectively, the resonant frequencies of tuning circuits 117 and 119 may be equal or substantially equal, referred to herein as tuning or being tuned. In some embodiments, the resonant frequency of tuning circuits 117 and 119 may be selected such that it corresponds substantially with the expected transmission frequency for data between collar 105 and probe 107. In some embodiments, substantially equal as used herein may mean wherein the resonant frequencies of collar tuning circuit 117 and probe tuning circuit 119 are within 5%, 1%, or 0.1% of each other. In some such embodiments, collar tuning circuit 117 and probe tuning circuit 119 may be tuned at substantially one resonant frequency or one resonant frequency band. In some embodiments, this may be referred to as “single-tuned” circuits. In some embodiments, the tuned frequency may not be limited to one. In some embodiments, collar tuning circuit 117 and probe tuning circuit 119 may be referred to as “dual-tuned”, and may, for example and without limitation, include one or more secondary inductors and capacitors, which may allow collar tuning circuit 117 and probe tuning circuit 119 to be tuned at two resonant frequencies (e.g. a lower resonant frequency and higher resonant frequency). In some embodiments, the secondary inductor and capacitor may form, for example and without limitation, a parallel LC trap. In some embodiments, one of the resonant frequencies, for example the lower resonant frequency, may be used to transfer electrical power through inductive coupler 103, while the higher resonant frequency may be used to transfer electrical signals or data. In some embodiments, such a dual-tuned tank circuit may be a combination of parallel and series resonant tanks. In some embodiments, the lower frequency may be, for example and without limitation, 20 Hz, 50 Hz, 60 Hz or 100 Hz. In some embodiments, the higher frequency may be, for example and without limitation, 500 Hz, 1 MHz, or 2 MHz.

In some embodiments, the mutual inductance M between coils 109 and 113 may be given by:

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$$M = k\sqrt{L_1 L_2}$$

where k is the coupling coefficient between coils **109** and **113**. In some embodiments, by increasing the mutual inductance M , the bandwidth available for data transmission about the resonant frequency of tuning circuits **117** and **119** may be proportional to the mutual inductance M . The coupling coefficient k may be expressed as:

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

In some embodiments, such as for power transfer across inductive coupler **103**, the coupling coefficient k may be, for example and without limitation, between 1.0 and 0.7. In some embodiments, such as for signal or data transfer, the coupling coefficient k may be, for example and without limitation, between 0.5 and 0.1. One having ordinary skill in the art with the benefit of this disclosure will understand that the coupling coefficients described herein are not intended to limit the scope of this disclosure. In some embodiments, such as for simultaneous power and signal transfer, additional low-pass filters, high-pass filters, band-pass filters, and/or band-rejection filters may be included. In some embodiments, impedance-matching circuits such as, for example and without limitation, additional transformers, may be used with the dual-tuned circuits.

In some embodiments, the mutual inductance M between two coils may be given by:

$$M = \frac{N_2 \Phi_{21}}{I_1} = \frac{(\mu_0 \pi R_2^2)}{2R_1} N_2$$

where μ_0 is the magnetic constant, N_2 is the number of turns in the second coil, I_1 is the current in the first coil, R_1 is the radius of the first coil, and R_2 is the radius of the second coil where the second coil is larger than the first coil. Based on these equations, without being bound to theory, reducing the distance between the first and second coil may, for example and without limitation, increase mutual inductance M and may improve the coupling coefficient.

In some embodiments, data may be transmitted across a threaded connection between subcomponents of downhole tool **101** or different downhole tools **101**. For example, in some embodiments, as depicted in FIG. 4, downhole tool **101** may include primary collar **121** as a first subcomponent and intermediate collar **123** as a second subcomponent. In some embodiments, primary collar **121** and intermediate collar **123** may be, for example and without limitation, parts of a motor, turbine, rotary steerable system, MWD, LWD, or drill bit where probe **107** is a mandrel. Primary collar **121** may be coupled to intermediate collar **123** by threaded coupling **125** having inductive coupler **127**. Although depicted as part of collar **105**, one having ordinary skill in the art with the benefit of this disclosure will understand that primary collar **121** and intermediate collar **123** may be part of any component of downhole tool **101**. Threaded coupling **125** may, in some embodiments, include male coupler **129** and female coupler **131** formed on primary collar **121** and intermediate collar **123** respectively.

As depicted in FIG. 4A, inductive coupler **127** may include male coil **133** positioned on male coupler **129** and female coil **135** positioned on female coupler **131**. In some such embodiments, when male coupler **129** is engaged with

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female coupler **131**, male coil **133** may be at least partially within female coil **135**. In some embodiments, male coupler **129** and female coil **135** may operate as described herein above with respect to collar coil **109** and probe coupler **113**.

In some embodiments, collar transceiver **111** may be positioned in primary collar **121** and collar coil **109** may be positioned in intermediate collar **123**. In some embodiments, inductive coupler **127** may transmit signals generated by collar transceiver **111** or probe transceiver **115** across threaded coupling **125**. Although described with respect to a collar, one having ordinary skill in the art with the benefit of this disclosure will understand that inductive coupler **127** may be utilized to transmit data across any threaded connection without deviating from the scope of this disclosure.

In some embodiments, intermediate collar **123** may include intermediate tuning circuit **137**. Intermediate tuning circuit **137**, as depicted in FIG. 5, may operate as described herein above with respect to tuning circuits **117** and **119**. In some embodiments, intermediate tuning circuit **137** may include primary tuning circuit **139a** which may include one or more components including, for example and without limitation, capacitor **141a** and resistor **143a**. Primary tuning circuit **139a** may be used to tune female coil **135** to male coil **133** as previously described. In some embodiments, intermediate tuning circuit **137** may include secondary tuning circuit **139b**, which may be used to tune collar coil **109** to probe coil **113** as previously described. In some embodiments, intermediate tuning circuit **137** of intermediate collar **123** may operate passively, in that intermediate tuning circuit **137** may include no power supply such as a battery within centralizer **145** (described hereinbelow). In some embodiments, intermediate tuning circuit **137** of intermediate collar **123** may include a battery operated repeater. In some embodiments, as discussed herein above, intermediate tuning circuit **137** may include one or more series tank circuits or parallel tank circuits. In some embodiments, as discussed herein above, intermediate tuning circuit **137** may include one or more single-tuned tank circuits or dual-tuned circuits.

In some embodiments, as depicted in FIG. 6, centralizer **145** may be positioned between collar **105** and probe **107**. Centralizer **145** may, for example and without limitation, support probe **107** within collar **105**. Centralizer **145** may include centralizer body **146**. In some embodiments, centralizer body **146** may be formed from a nonmagnetic material such as rubber.

In some embodiments, centralizer **145** may be positioned such that it is at least partially within collar coil **109** and probe coil **113** is at least partially within centralizer **145**. In some embodiments, centralizer **145** may include outer coil **147** and inner coil **149**. Outer coil **147** may be positioned on or near outer surface **151** of centralizer body **146** and inner coil **149** may be positioned on or near inner surface **153** of centralizer body **146**. In some embodiments, outer coil **147** and inner coil **149** may be electrically coupled. In some embodiments, centralizer **145** may allow signals and/or low-frequency power generated by collar transceiver **111** or probe transceiver **115** to be transmitted therethrough.

In some embodiments, centralizer **145** may include centralizer tuning circuit **155**. Centralizer tuning circuit **155**, as depicted in FIG. 7, may operate as described herein above with respect to intermediate tuning circuit **137** and may include one or more parallel resonant tanks. In some embodiments, centralizer tuning circuit **155** may include primary tuning circuit **139a** which may include one or more components including, for example and without limitation, capacitor **141a** and resistor **143a**. Primary tuning circuit

139a may be used to tune outer coil 147 to collar coil 109. In some embodiments, centralizer tuning circuit 155 may include secondary tuning circuit 139b, which may be used to tune inner coil 149 to probe coil 113. In some embodiments, centralizer tuning circuit 155 may operate passively, such that centralizer tuning circuit 155 may include no power supply such as a battery. In some embodiments, centralizer tuning circuit 155 may include a battery-operated repeater.

In some embodiments, as depicted in FIGS. 8, 9, centralizer 145 may be generally annular. Centralizer body 146 may, in some embodiments, be formed from inner annular segment 157 and outer annular segment 159. Inner annular segment 157 may be mechanically coupled to outer annular segment 159 by one or more radial spokes 161. For example, in some embodiments, as depicted in FIG. 8, inner annular segment 157 may be mechanically coupled to outer annular segment 159 by two radial spokes 161. In some embodiments, as depicted in FIG. 9, inner annular segment 157 may be mechanically coupled to outer annular segment 159 by three radial spokes 161. In some embodiments, outer coil 147 may be positioned within outer annular segment 159 and inner coil 149 may be positioned within inner annular segment 157. In some embodiments, centralizer tuning circuit 155 may be positioned within inner annular segment 157, outer annular segment 159, radial spokes 161, or a combination thereof. In some embodiments, radial spokes 161 may define flow paths (not shown) through which fluid may pass between probe 107 and collar 105 through centralizer 145.

In at least one embodiment of the present disclosure, an inductive coupler for a downhole tool may include a first transceiver electrically coupled to a first coil through a first tuning circuit and a second transceiver electrically coupled to a second coil through a second tuning circuit, the second coil positioned substantially concentric with the first coil. The first transceiver may be collar transceiver 111 or probe transceiver 115. The first coil may be collar coil 109, probe coil 113, male coil 133, female coil 135, outer coil 147, or inner coil 149. The first tuning circuit may be collar tuning circuit 117, probe tuning circuit 119, intermediate tuning circuit 137, primary tuning circuit 139a, secondary tuning circuit 139b, or centralizer tuning circuit 155. The second transceiver may be collar transceiver 111 or probe transceiver 115. The second coil may be collar coil 109, probe coil 113, male coil 133, female coil 135, outer coil 147, or inner coil 149. The second tuning circuit may be collar tuning circuit 117, probe tuning circuit 119, intermediate tuning circuit 137, primary tuning circuit 139a, secondary tuning circuit 139b, or centralizer tuning circuit 155.

In some embodiments, the distance between adjacent coil pairs, such as between collar coil 109 and probe coil 113, male coil 133 and female coil 135, outer coil 147 and collar coil 109, or inner coil 149 and probe coil 113, may, for example and without limitation, be less than 0.5", less than 0.25", or between 0.0625" and 0.25". In some embodiments, collar coil 109, probe coil 113, male coil 133, female coil 135, outer coil 147, or inner coil 149 may be spaced between 0.125" and 0.5" of the edge of the corresponding structure—collar 105, probe 107, male coupler 129, female coupler 131, outer surface 151, or inner surface 153 respectively.

The foregoing outlines features of several embodiments so that a person of ordinary skill in the art may better understand the aspects of the present disclosure. Such features may be replaced by any one of numerous equivalent alternatives, only some of which are disclosed herein. One of ordinary skill in the art should appreciate that they may readily use the present disclosure as a basis for designing or

modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. One of ordinary skill in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

The invention claimed is:

1. A centralizer for supporting a probe within a collar of a downhole tool, the collar including a collar coil and the probe including a probe coil, the centralizer comprising:

- an annular centralizer body;
- an outer coil, the outer coil positioned at an outer surface of the centralizer body; and
- an inner coil, the inner coil positioned at an inner surface of the centralizer body, the inner coil electrically coupled to the outer coil through a centralizer tuning circuit, wherein the centralizer tuning circuit comprises a primary tuning circuit having a first resonant frequency and a secondary tuning circuit having a second resonant frequency; and

wherein the primary tuning circuit is configured to tune the outer coil to the collar coil and wherein the secondary tuning circuit is configured to tune the inner coil to the probe coil.

2. The centralizer of claim 1 wherein the outer coil is substantially concentric with the inner coil.

3. The centralizer of claim 1 wherein the primary and secondary tuning circuits each comprise a capacitor, and wherein the primary tuning circuit has a resonant frequency substantially equal to a resonant frequency of a tuning circuit positioned in the collar, and the secondary tuning circuit has a resonant frequency substantially equal to a resonant frequency of a tuning circuit in the probe.

4. The centralizer of claim 1 wherein the centralizer body comprises an inner annular segment and an outer annular segment and the inner and outer annular segments are mechanically coupled.

5. The centralizer of claim 4 wherein the inner annular segment and the outer annular segment define a fluid flow path therebetween.

6. The centralizer of claim 4 wherein the inner coil is positioned within the inner annular segment and the outer coil is positioned within the outer annular segment.

7. The centralizer of claim 1 wherein the centralizer body is formed from a nonmagnetic material.

8. The centralizer of claim 1 wherein the centralizer body is formed from rubber.

9. A downhole system comprising

- an annular collar with a collar coil;
- a probe, with a probe coil, positioned within the collar;
- a centralizer positioned between the probe and collar, the centralizer comprising:

- an annular centralizer body;
- an outer coil, the outer coil positioned at an outer surface of the centralizer body; and
- an inner coil, the inner coil positioned at an inner surface of the centralizer body, the inner coil electrically coupled to the outer coil through a centralizer tuning circuit;

wherein the centralizer tuning circuit comprises a primary tuning circuit having a first resonant frequency and a secondary tuning circuit having a second resonant frequency; and

wherein the primary tuning circuit is configured to tune the outer coil to the collar coil and wherein the

secondary tuning circuit is configured to tune the inner coil to the probe coil.

10. The downhole system of claim 9 wherein the collar includes a collar tuning circuit positioned therein, wherein the probe includes a probe tuning circuit positioned therein, 5 wherein the centralizer tuning circuit comprises a primary tuning circuit and a secondary tuning circuit, and wherein the primary tuning circuit has a resonant frequency substantially equal to a resonant frequency of the collar tuning circuit, and the secondary tuning circuit has a resonant 10 frequency substantially equal to a resonant frequency of the probe tuning circuit.

11. The downhole system of claim 9 wherein the centralizer body comprises an inner annular segment and an outer annular segment and the inner and outer annular segments 15 are mechanically coupled.

12. The downhole system of claim 11 wherein the inner annular segment and the outer annular segment define a fluid flow path therebetween.

13. The downhole system of claim 11 wherein the inner 20 coil is positioned within the inner annular segment and the outer coil is positioned within the outer annular segment.

14. The downhole system of claim 9 wherein the centralizer body is formed from a nonmagnetic material.

15. The centralizer of claim 9 wherein the centralizer 25 body is formed from rubber.

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